ANS
Aquatic Nuisance Species
DIGEST

Volume 2 No. 3 February 1998

FRESHWATER FOUNDATION

Providing current information on monitoring and controlling the spread of harmful nonindigenous species.

The New Zealand Mud Snail in Western North America

by Michael M. Gangloff

Two critical issues facing conservation agencies around the world are to control the spread and to deal with the effects of exotic species. Many mollusks (snails and clams, for example) have greatly expanded their range with the help of commerce and travel. When mollusks are accidentally or intentionally introduced into new ecosystems, their spread is often rapid. Mollusks possess numerous adaptations, such as planktonic larvae, high **fecundities**,* and watertight or buoyant shells, which allow them to effectively colonize new systems. Despite the prevalence of non-native mollusks in many systems throughout North America—Bowler and Frest (1992) report 12 species in western North America, and Mills et al. (1993) report 14 species in the Laurentian Great Lakes—their presence generally receives little attention unless a serious economic threat is posed. The economic consequences of molluscan invasions are generally felt in the form of biofouling problems (Mills et al. 1993).

words in **bold type are defined in the glossary on page 27.*

The New Zealand Mud Snail

The New Zealand mud snail *Potamopyrgus antipodarium* is indigenous to New Zealand and its adjacent islands, Stewart and Chatham islands (Winterbourn 1970b; Ponder 1988). During the 19th century it spread to Europe and then to Australia, probably carried with various ornamental aquatic plants to botanical collections transported to Europe. The first occurrence in Europe was reported in 1859 in England (Ponder 1988). Initial reports of the mud snail in Europe identified it as a similar but distinct species, *Potamopyrgus jenkinsi*, a species native to Europe. However, later analysis confirmed that *P. jenkinsi* was in fact *P. antipodarium* (Winterbourn, 1972). Mud snails were reported in Tasmania in 1872, and in Australia in 1895 (Ponder 1988).

***The New Zealand Mud Snail** continued on page 28*

Shrimp Virus Risk Management: A South Carolina Case Study

by Craig L. Browdy and A.F. Holland

Since 1980 US consumer demand for marine shrimp has grown at a rate of seven to nine percent annually, resulting in a 720 million pound market valued at over $2.6 billion (USJSA 1997). Imported shrimp account for over 80% of the US shrimp market (USJSA 1997). Because most wild shrimp fisheries are harvested at maximum sustainable levels, farm-reared shrimp provides an increasing proportion of the current market; shrimp farms currently provide about 22% of world shrimp production (Rosenberry 1997). Between 1985 and 1995, aquaculture production of shrimp expanded 430%, while the harvest of wild shrimp increased only 11% (New 1997). Establishment of a sustainable domestic supply of farmed shrimp would reduce the US reliance on imports, create a new industry suitable for rural coastal economies, and would provide an environmentally and economically sustainable alternative for filling the gap between the consumer demand for shrimp and the available wild-harvest supply. Outbreaks of nonindigenous shrimp viruses are the major problem limiting production and expansion of the shrimp farming industry in South Carolina and worldwide.

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Direct questions and comments about *ANS Digest* to: Freshwater Foundation, Gray Freshwater Center, 2500 Shadywood Road, Navarre, MN 55331; (612) 471-9773; e-mail: freshwater@freshwater.org.

Aquatic Nuisance Species Digest (ISSN 1083-8864) is produced by the Freshwater Foundation, a public nonprofit foundation whose mission is to pursue the sustainable use of freshwater resources through education, conferences, publications and research. *ANS Digest* is published quarterly in cooperation with the U.S. Fish and Wildlife Service and the national Task Force on Aquatic Nuisance Species.

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Champlain Canal Fish Barrier Study

by Michael Hauser

The announcement expected by many people in Vermont, New York, and Quebec was finally made in June 1993—zebra mussels had been found in Lake Champlain. Previously, the exotic mussels had been advancing through the St. Lawrence River system to the north and the Hudson River system to the south. Both river systems are connected to the 128-mile-long lake; the St. Lawrence via the Richelieu River, and the Hudson via the Champlain Canal (see map). Surveys during the summer of 1993 found zebra mussels in only the extreme southern end of the lake, pointing to the 80-year-old Champlain Canal as the likely vector—again. Other nonnative aquatic species including sea lamprey, white perch, and water chestnut had likely entered the lake through this "front door."

The discovery of zebra mussels in Lake Champlain underscored the significant role the Champlain Canal plays in species introductions to the Lake Champlain Basin, and further justified a study that was underway by the New York State Department of Environmental Conservation (NYSDEC). As early as 1989, NYSDEC had begun to investigate the feasibility of erecting a barrier in the Champlain Canal to prevent another exotic species, the alewife, from entering the lake. The alewife had caused substantial ecological changes in several of the Great Lakes after entering that region via canals; biologists feared that it could have similar consequences in Lake Champlain. Of particular concern were the important smelt and yellow perch fisheries.

Ironically, the potential for aquatic species introductions to Lake Champlain via the Champlain Canal had increased in recent years due to substantial improvements in Hudson River water quality. For much of the canal's history, the Hudson River was heavily polluted in the vicinity of Fort Edward, New York (see map), where the canal diverges from the river. Pollution may have acted as a chemical barrier preventing species from moving into the canal. A possible case in point is the fact that white perch only recently became established in Lake Champlain despite a much longer presence in the Hudson River.

In March 1992, with funding from the Lake Champlain Basin Program, NYSDEC entered into a two-phase contract with Smith-Root, Inc. of Vancouver, Washington. Under the first phase, Smith-Root developed a conceptual design for an electrical fish barrier on the Champlain Canal. Under phase two, detailed engineering and cost estimates were developed.

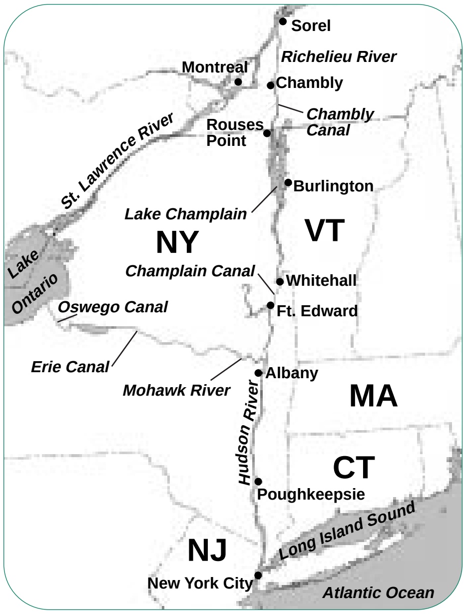
The Lock 7 site at Fort Edward, New York, (see map) was targeted for the study. Because of its location at the mouth of the canal, fish repelled by a barrier at that site could be swept away by the faster current of the Hudson River. A barrier farther into the canal would cause a "pile-up" of fish which would increase the potential for penetration. Smith-Root engineers also determined that the Lock 7 site had the necessary infrastructure for installation and operation of an electrical fish barrier.

Electrical barriers are generally classified as behavioral barriers because they produce a stimulus intended to alter the action of targeted organisms rather than physically preventing their passage. Smith-Root also examined and ruled out other types of behavioral barriers, including high-frequency sound, flashing strobe lights, louver screens, velocity gradients, chemicals, magnetic barriers, and air-bubble screens. Physical barriers, while proven effective in some applications, were not considered for the Champlain Canal application because they would interfere with the movement of boats and barges through the canal.

The electrical barrier system proposed by Smith-Root uses bottom and side-mounted electrodes to generate non-lethal direct-current pulses throughout the water column. According to Smith-Root, such pulses have proven effective at repelling alewives and most other fish species in other applications. The electrodes are flush-mounted in pre-cast concrete panels to reduce the potential for human contact and to prevent the collection of debris. They would be connected above ground to electric pulsators housed inside an insulated equipment building. The barrier's electric pulse is designed to startle, but not to stun or to inhibit the normal swimming ability of fish, so that fish entering the field will have the ability to retreat. The barrier would be ineffective if a fish were temporarily paralyzed and flushed through the field by water currents.

***Canal** continued on next page*

Canal *continued from previous page*



Waterway from New York City to Montreal

Human safety was a primary concern for potential design and operation of the barrier. Smith-Root has installed electrical fish barriers at many sites throughout the country, but none of the sites received regular boat traffic. Although Smith-Root believe their electric barriers would not be lethal to humans, they typically recommend that the barriers be turned off for liability reasons when humans are within it. However, turning the electric barrier off each time a boat entered into the Champlain Canal would cause a substantial breech in the barrier. For this reason Smith-Root and NYSDEC discussed a variety of operational and safety alternatives, including the possibility of leaving the barrier turned on even when boats moved through it.

Potential safety features included covering the side electrode panels with heavy planks extending above the water surface to prevent humans from coming into direct contact with the electrodes, posting signs to warn boaters against mooring or anchoring within the immediate area of the barrier, the installation of railroad-style gates at each end of the barrier to control boat movement through the barrier, and increasing the water flow through the barrier in order to carry a person out of the electric field more quickly should someone fall into the water. Another safety feature that was discussed involved the installation of motion sensors to detect objects about to move into the barrier. As a boat, person, or other object within the canal approached the barrier, it would automatically switch off, during which time an interim barrier such as a sonic fish-repellent device would be activated. Sonic devices, although potentially safer than electric barriers, were considered to be less effective at repelling fish when used for an extended period, but could provide effective short-term protection.

Smith-Root's electric barriers have been determined to be effective at repelling fish and appear to be safe to humans. The operators at a site near Phoenix, Arizona, where two barriers are deployed, reported that a child on an inner-tube, a horse, and a dog have safely passed through the barriers. The dog was reported to have shaken for a while (the reason why was not reported—it simply may have been cold or frightened), but the others were apparently unaffected. At another site in Detroit, Michigan, operators reported that boats had entered the field with no apparent effects on equipment or on humans.

As required by Phase Two of the contract, Smith-Root produced engineering drawings and estimated that the completed project would cost between $250,000 and $500,000, depending on the safety measures that were incorporated. Human safety and liability remained a primary concern for the project, and although measures were identified that could address those concerns, specific plans for each of the proposed safety devices were not produced. Additionally, funding to install a barrier in the Champlain Canal has not been allocated and there are currently no plans to do so.

Meanwhile Lake Champlain continues to be vulnerable to aquatic species introductions from the Hudson River System via the Champlain Canal. As far as the alewife is concerned, closing the "front door" to Lake Champlain may not be enough. During the summer of 1997, a large population of alewives were found in Vermont for the first time in Lake St. Catherine, an 883 acre lake just twelve miles from Lake Champlain. Alewives were likely introduced to Lake St. Catherine via bait releases, a practice which could easily bring the aggressive species in the "back door" to Lake Champlain. There are many other species that could make their way from the Great Lakes to Lake Champlain—round goby, ruffe, and others yet to be identified. Perhaps a success of the current effort to install a similar electrical barrier in the Chicago Ship Canal to prevent the round goby from moving into the Mississippi drainage basin (see "Controlling Round Gobies" in *ANS Digest*, Vol. 2, No. 2) will renew interest in the Champlain Canal barrier.

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Glossary

Benthic

Organisms that live on or near the bottom of a lake, river, or other body of water.

Estuaries/Estuarine

An estuary is the part of the mouth of a river that meets the sea; estuarine (adjective), found in an estuary.

Fecundities

The ability to produce many offspring.

Gastropod

Of the class of mollusks that includes snails and slugs.

Lampricide

A chemical used to kill sea lamprey.

Lentic

Pertaining to nonflowing bodies of fresh water, such as lakes, ponds, wetlands, or bogs.

Macroinvertebrates

Larger invertebrates (as opposed to microscopic organisms).

Periphyton

Organisms attached to or clinging to plants or other objects projecting above the bottom sediments of freshwater lakes, ponds, streams, etc.

Pharyngeal

Located near the pharynx, which connects the mouth to the esophagus, that is, the back of the throat.

Trematode

A parasitic flatworm of the class Trematoda, having one or more external suckers.

The New Zealand Mud Snail

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Mud Snails in North America

Mud snails were first documented in North America in the Middle Snake River, Idaho, in 1987, probably having escaped from a fish farm (Bowler 1990). In Idaho they have been collected in the Snake River from American Falls to the Thousand Springs area, in the Buffalo River, and in Box Canyon Creek, a tributary of the Snake River (see Figure 1) (Bowler 1990; Bowler and Frest 1992). From Idaho, they were carried across the Continental Divide (probably in "damp media," discussed below) to the Upper Madison River and its tributaries in Montana and Wyoming (Bowler and Frest 1992; D. L. Gustafson, pers. com.). Recent surveys in this watershed indicate that mud snails have spread to the Firehole and Gibbon rivers and to Nez Perce Creek in Yellowstone National Park (M. Dybdahl, M. Gangloff, B. Kerans, unpub. data; D. Richards unpub. data). At the present time it is thought that the distribution of mud snails is limited to the Madison River above Hebgen Reservoir, but the reservoir itself and its tributaries have not been extensively surveyed. In 1991 mud snails were collected from Lake Ontario (see Figure 1); it is thought that this invasion occurred independently of Snake River populations. Zaranko et al. (1997) speculated that they were introduced via ballast water of European commercial vessels. The most recent invasion on the North American continent was documented on the lower Columbia River near Astoria, Oregon, by workers at the National Marine Fisheries Service (see Figure 1) (S. Hinton, pers. com.). It is thought that this population was introduced via ballast water independently of upstream populations in the Snake River.

Biology of Mud Snails

New Zealand mud snails are members of the **gastropod** order prosobranchia, the lungless snails, which are distinguished from other gastropods by the presence of an operculum—a solid calcified covering which fits tightly over the shell's opening. Mud snails reach an average length of five millimeters, about the width of a paper clip (see Figure 2). Because they lack lungs, the long range dispersal of mud snails is restricted to transport in damp media or underwater. However, the operculum is capable of forming a fairly tight seal and specimens have been reported to survive out of water for several hours, depending on temperature and humidity (M. Dybdahl pers. com.). If kept in a damp surrounding (such as a wading boot tread or a Velcro strap), the snail's survival time increases markedly; Winterbourn (1970b) observed 50% survival after 25 days in "damp media." It is likely that dispersal in a "damp media" was responsible for the species' spread from Idaho to Montana and Wyoming

Mud snails can reproduce by parthenogenesis, whereby a female produces offspring without being fertilized by a male. These offspring are genetically identical to the parent. The young snails emerge as fully functional versions of the adult, complete with immature larva developing in their ovaries. Clonal populations are almost all female, the few males that are produced are not reproductively viable. This parthenogenic reproductive capacity makes them well suited for successful invasions because they have the reproductive capacity to easily cause new infestations.

In New Zealand, mud snails are parasatized by a **trematode** that causes sterility. Populations co-occurring with the trematode have been found to reproduce sexually, but earlier and at smaller sizes before they can be infected. Invasive populations and those which occur in the absence of the parasite rarely undergo sexual reproduction (Winterbourn 1973b; Lively 1992; Jokela and Lively 1995; Fox et al. 1996). Populations in North America have been found to be predominately female and so far no sign of any trematode infections has yet been recorded (M. Dybdahl, pers. com.).

Figure 1

Known distribution and date of first documented occurrence of P. antipodarium *in North America. Dates correspond to the following localities: 1987 Middle Snake River, Idaho; 1991 Lake Ontario near Wilson, New York; 1994 Lake Ontario near St. Lawrence River origin; 1995 upper Madison River and tributaries, Montana/Wyoming; 1997 Columbia River at Astoria, Oregon.*

Effects of Mud Snails

Mud snails could cause several problems which are of concern to ecologists and to managers. Paramount among these is the concern that mud snails may be outcompeting native gastropods in North America, some of which are threatened or endangered. There is little evidence to suggest what effect, if any, it has had on snail faunas in Europe and Australia. In Idaho's Middle Snake River, in addition to outright competition for food, it is thought that mud snails compete with native snails for moist refugia (such as undersides of rocks) during water-level fluctuations (Bowler 1990). A more direct but inherently subtle form of competition is crowding; several researchers have reported mud snail densities in excess of 50,000 individuals per square meter (/m^2) (Hylleberg and Siegismund 1987; Schreiber et al. 1997). Although the effects of these densities must be regarded as strictly speculative, it is possible that at high densities mud snails

***Snail** continued on next page*

Snail *continued from previous page*

may simply exclude other grazing organisms by their sheer numbers. A third possible effect may be competition with other **macroinvertebrates** for **periphyton**. Studies have shown that snails are capable of changing both algal densities and community composition in stream systems (Hawkins and Furnish 1987; Winterbourn and Fegley 1989). Winterbourn and Fegley (1989) noted in their grazing studies that mud snails were capable of influencing periphyton biomass, but offered no data to support this claim. Despite their now wide distribution in Europe and Australia, few studies have quantitatively explored the effects of mud snails on native gastropods.

In their native range, mud snails are found in many habitat types including **estuaries** (Winterbourn 1973a). Besides the trematode, they have few natural enemies. Studies show that mud snails, thanks to their strong shell and opercula, are capable of passing through the digestive canal of most fish alive and intact (Bondesen and Kaiser 1949; Haynes et al 1985). Even if fish are able to crush the shells, mud snails are a poor source of energy compared to other prey (Ryan 1982). In New Zealand and Australia, short-finned and long-finned eels *(Anguilla australis* and *A. dieffenbachii)* and brown trout *Salmo trutta* have been reported with mud snails in their intestinal tracts, but it is unclear if these accounts represent actual targeted feeding behavior or if individuals found in stomach samples were accidentally ingested with other prey (Burnet 1969; Cadwallader 1975). It has been suggested some species of fish that possess **pharyngeal** teeth may be more likely to eat mud snails. Despite the apparent lack of predatory control, mud snails are seldom considered a nuisance in their native habitat. While mud snails are the dominant organism in several studies (Towns 1981a; Towns 1981b; Scott et al. 1994), they are not dominant in all systems; several researchers found mud snails absent or occurring at low densities (Winterbourn 1978; Rounick and Winterbourn 1982; Scrimgeour and Winterbourn 1989; Scarsbrook and Townsend 1993). In general, patterns in the occurrence and dominance of mud snails have not been quantitatively investigated, but Ponder (1988) observed that mud snails in Australia were mostly confined to "degraded" habitats.

Mud snail populations in Europe and Australia have been the subject of many systematic and life-history studies over the last three decades. Early research attempted to clarify the controversy over whether or not *P. jenkinsi* and *P. antipodarium* were the same species, and whether they were introduced or native (Winterbourn 1972; Ponder 1988). Some work has been done on the dispersal mechanisms and the factors affecting the establishment of mud snails within **lentic** and **estuarine** systems (Ribi 1986; Siegismund and Hylleberg 1987). Ribi (1986) found that mud snails in Swiss lakes disperse at a rate of 1.0 square meters per day (m^2/d). Haynes et al. (1985) report a similar maximum dispersal rate of 1.2 m^2/d. In Australia, Ponder (1988) reported that mud snail densities fluctuate wildly with seasonal highs of 50,000/m^2 during the Australian summer months and lows of 1,800/m^2 during the winter (Schreiber, et al. 1997). Similarly, Siegesmund and Hylleberg (1987) found that mud snails in Danish estuaries that freeze would die back but would quickly re-colonize at densities approaching 50,000/m^2 in the summer. This pattern of fluctuation is consistent with observations of mud snail populations elsewhere and may indicate that temperature could restrict their dispersal, population dynamics, and seasonal densities.

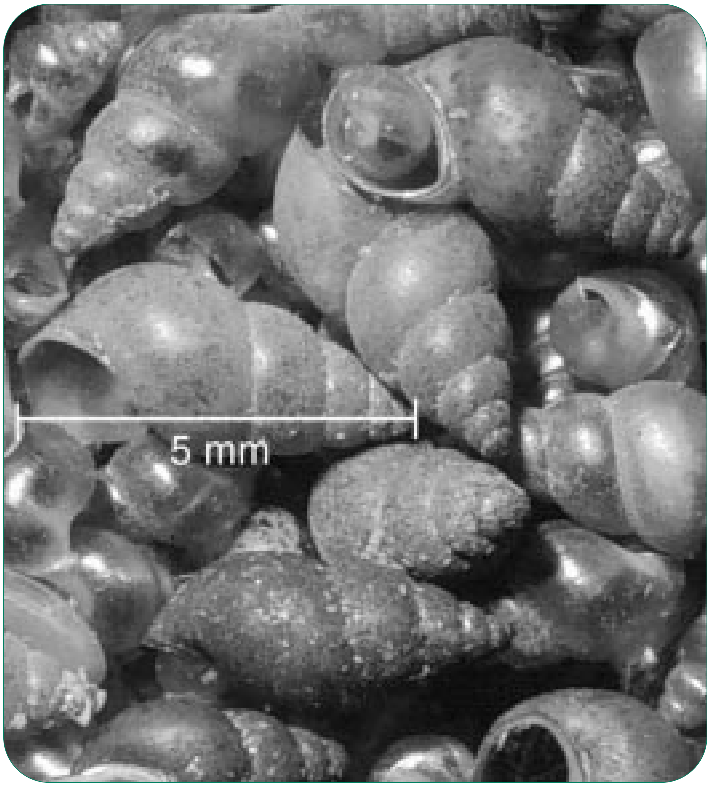

Figure 2

The New Zealand Mud Snail Potamopyrgus antipodarium.

Conclusion

Although there has been little work on competition between mud snails and native gastropods, observations suggest that some competition may be occurring. Mud snails have already expanded to four locations in North America, all of which offer excellent potential for significant range expansion. Populations in the Great Lakes could disperse throughout midwestern and southern North America with little impediment, and the two known populations in the Columbia River system could become established within the entire main river and the lower reaches of its tributaries. The population in the Upper Madison River appears to be the most isolated of the four, but Hebgen Reservoir should present little impediment to its dispersal. The current distribution, invasiveness, and ecological effects of mud snails in the Madison River and the Greater Yellowstone ecosystem are being investigated by a group of researchers from Montana State University–Bozeman (M. Gangloff and B. Kerans) and Indiana University–Bloomington (M. Dybdahl). Researchers plan to use a series of field surveys, laboratory and field experiments, and genetic studies of snail populations to explore their biology, ecology, effects, and distribution. At this time, potential effects of mud snails remain speculative, but competition with native snails, limitation and alteration of stream periphyton communities, and restructuring of ecosystem function are all possible consequences.

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Snail *continued on page 30*

Upcoming Meetings

8th International Zebra Mussel and ANS Conference
16-19 March 1998
Double Tree Sacramento,
Sacramento, CA
Contact: Jodi Cassell,
University of California Sea Grant
(415) 871-7559
email: jcassell@ucdavis.edu
http://www.zebraconf.org

Western Regional Panel Meeting
18 March 1998, 1:30 to 5:30
Double Tree, Sacramento
(During the 8th International Zebra Mussel and ANS Conference)

ANS Task Force Meeting
19-20 March 1998
Red Lion Inn, Sacramento, CA
Contact: Bob Peoples,
US Fish & Wildlife Service
(7030 358-2025; email:
robert_peoples@fws.gov

Send meeting announcements to:

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Deadline for the next issue is 15 April 1998

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• •NEW• • ANS Video from Oregon State University

Oregon State University at Corvallis has released a new informational video entitled

Strangers in Our Waterways.

The video explores how the introduction of nonindigenous aquatic organisms–such as fish, shellfish, and aquarium plants–has affected native organisms in and around our waterways. It discusses how some nonindigenous organisms have displaced, endangered, or eliminated native aquatic and terrestrial organisms. *Strangers in Our Waterways* may be of interest to:

- natural resources or
- environmental educators;
- natural resources management groups;
- anglers and fishing enthusiasts.

Strangers in Our Waterways (VTP 023) is available in VHS format from Oregon State University for $30 (includes shipping and handling). For information, call (541) 737-2513, or write to:

Agricultural Communications
Oregon State University
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News from the Great Lakes Panel on Aquatic Nuisance Species

ANS UPDATE

Fall 1997 Volume 3 No. 4

Great Lakes Panel Update

The Panel met Dec. 17-18, 1997, in Ann Arbor, Mich., where special focus was directed on two new projects: model state legislation for ANS prevention and control and a regional ANS Action Plan. The Panel invites input on these projects from all interested parties. Also, Panel committees (information/education, policy and legislation, and research coordination) convened to advance their respective work plans. Other meeting items included updates on national ANS Task Force activities, federal appropriations, the Ballast Technology Demonstration Project, model guidelines for ballast water management, and the new Chicago Waterways Dispersal Barrier Project. Minutes from the meeting are available upon request. Contact: Matt Doss, Great Lakes Commission, 313-665-9135, mdoss@glc.org.

Washington Watch

Appropriations bills relevant to the National Invasive Species Act of 1996 (NISA) have been passed by Congress and signed by the President. These appropriations reflect an overall increase in NISA funding.

Through NISA, the U.S. Army Corps of Engineers was provided $2.0 million for research on zebra mussels, an increase of $500,000. To support invasive aquatic plant control research, $5 million was appropriated to the Corps through The Rivers and Harbors Act. An additional $500,000 was given to the Corps to begin construction of an ANS dispersal barrier between the Great Lakes and Mississippi River systems at the Chicago Sanitary and Ship Canal. The U.S. EPA received $250,000 for dispersal containment analysis in association with this project.

Funding for NISA implementation in the Department of Interior has also expanded with an additional $1 million in funding, providing a total of $2.192 million for the ANS program directed by the U.S. Fish and Wildlife Service.

Increased funding for the U.S. Coast Guard, totaling $1.995 million, will support the Great Lakes Ballast Water Management program. The program includes expansion of ballast water guidelines to national status, ballast discharge studies, establishment of the National Ballast Water Clearinghouse and research on nonchemical ballast management practices for fully loaded vessels.

The National Oceanic and Atmospheric Administration (NOAA) received $1.5 million in new funding for NISA implementation in association with its co-leadership of the ANS Task Force and Ballast Water Demonstration programs. NOAA's Great Lakes Environmental Research Lab, responsible for much of ANS research on the Great Lakes, received $6 million in base funding, an increase of $800,000. Sea Grant received $56 million, a portion of which will support zebra mussel research. **Contact:** Rochelle Sturtevant, Senate Great Lakes Task Force, 202-224-4229, rochelle_sturtevant@glenn.senate.gov.

News From Around The Basin

INDIANA: The DNR is approving an approach for ANS state management plan development. A timetable, cost estimate and review process are being identified. **Contact:** Randy Lang, IN DNR, 317-232-4094, randy_lang_dnrlan@ima.isd.state.in.us.

NEW YORK: The Lake Champlain Basin program is developing an interstate, watershed ANS management plan. Under the state management plan, DEC has been awarded a $20,000 grant from the U.S. Fish and Wildlife Service to continue a program for assessing the impacts of zebra mussel colonization on aquatic ecosystems in the Finger Lakes ecoregion. A pamphlet, *Common Nuisance Aquatic Plants in New York State,* has been published by the DEC as part of the state management plan. **Contact:** Tim Sinnott, NYS DEC, 518-457-0758, txsinnot@gw.dec.state.ny.us.

OHIO: Ohio's ANS Advisory Team met in October to review and evaluate ANS information/education materials and programs. In the upcoming months, work will focus on prioritizing and developing I/E projects. Participation in regional and national conferences is an important component of Ohio's outreach program regarding the state's ANS prevention and control efforts. **Contact:** Randy Sanders, OH DNR, 614-265-6344, randy.sanders@dnr.state.oh.us.

ONTARIO: *A National Policy on Introductions and Transfers of Aquatic Organisms* is being developed in Canada. The policy, which is to be completed in 1998, addresses intentional sources and some accidental sources of ANS introduction. According to a recent exotic fish mail survey, sightings of the rudd, a European minnow, has been confirmed in western Lake Ontario and the tubenose goby in western Lake Erie. **Contact:** Alan Dextrase, OMNR, 705-755-1950, dextraal@epo.gov.on.ca.

PENNSYLVANIA: DEP's monitoring program has not indicated any range expansion of zebra mussel populations. The lack of range expansion from Pennsylvania's portion of Lake Erie into inland lakes of Erie County was noted to be "quite remarkable" by Erie County Department of Health personnel, considering the proximity of the county's lakes and abundance of boaters. This trend is, in part, attributed to public awareness and unknown biological limiting factors preventing zebra mussel establishment in these lakes. **Contact:** Tony Shaw, PA DEP, 717-787-9637, shaw.tony@al.dep.state.pa.us.

On The Bookshelf

- *Common Nuisance Aquatic Plants in New York State.* NYS DEC Lake Services Section. October 1997. **Contact:** Tim Sinnott, NYS DEC, 518-457-0758, txsinnot@ gw.dec.state.ny.us.
- *Changes in the Freshwater Mussel Community of Lake St. Clair: From Unionidae to Dreissena polymorpha in Eight Years.* T. Nalepa, D.J. Hartson, G.W. Gostenik, D.L. Fanslow and G.A. Lang. *Journal of Great Lakes Research,* 22:354-69. Authors were awarded the 1996 Chandler-Misener Award presented by the *International Association for Great Lakes Research.*

A full copy of the latest issue of the *ANS Update* (Vol. 3, No. 4), a quarterly newsletter prepared by the Great Lakes Panel on Aquatic Nuisance Species, is available upon request from the Great Lakes Commission. The feature article of this issue is authored by Dr. Phil Moy, a fisheries biologist from the U.S. Army Corps of Engineers, Chicago District; and is titled, *An ANS Dispersal Barrier for the Great Lakes and Mississippi River Basins.* **Contact:** Kathe Glassner-Shwayder, Great Lakes Commission, 313-665-9135, shwayder@glc.org.

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Shrimp Farming in South Carolina

Some of the first efforts to develop shrimp farming in the US occurred in impounded wetlands created from old rice fields in South Carolina (Lunz 1951). By 1995 a small shrimp farming industry consisting of 18 farms and producing over 500 metric tons (MT) of shrimp had become established in South Carolina, based upon technologies developed with the Waddell Mariculture Center of the South Carolina Department of Natural Resources. The culture species of choice historically has been the Pacific white shrimp *Penaeus vannamei*. The specific pathogen-free, genetically improved supplies of this species outperform indigenous shrimp under good culture conditions (Sandifer et al. 1993).

The Department is responsible for protecting and managing South Carolina's commercial and recreational shrimp fishery. Laws which regulate the shrimp farming industry require the Department to ensure that importation of nonindigenous shrimp for aquaculture will not adversely affect the state's wild shrimp populations.

Effects of Shrimp Viruses

Although harmless to humans, infections by viruses frequently cause high mortalities and near total loss of shrimp crops. Shrimp virus infections reduced the US farmed shrimp production by about 50% in recent years (Rosenberry 1995, 1996). Since 1994 global production of farmed shrimp has decreased from 733,000 MT in 1994 to an estimated 660,000 MT (Rosenberry, 1997). This decline can be attributed largely to shrimp viruses.

Shrimp viruses may be transferred through importation of infected seed stocks, in fresh or frozen product for human consumption, with carrier organisms in ship ballast water, in fresh or frozen bait shrimp, and other pathways. Once a viral agent is introduced into a shrimp pond, it may be more rapidly amplified than in the natural environment. Researchers believe this is because:

- the availability of virus particles to pond-reared shrimp is high compared to the availability of virus particles to wild shrimp;
- the virulence of the viral agents is frequently greater in the stressful pond environment than in the wild, and;
- sick and dying shrimp that contain large numbers of infectious viral particles are rapidly eaten by healthy shrimp, spreading the disease throughout the pond population. In the wild, sick shrimp would have a greater chance of being eaten by other predators before they could be cannibalized by another shrimp.

Types of Shrimp Viruses

Lightner et al. (1997) report that over 20 viruses are recognized for penaeid shrimp (shrimp of the family penaeidae, which includes most grocery-store varieties of shrimp). There are four viruses of particular concern to South Carolina farmers and to the Department: Taura Syndrome Virus; White Spot Virus; Yellow Head Virus; and Infectious Hypodermal and Hematopoietic Necrosis Virus.

Taura Syndrome Virus (TSV) was first reported from Ecuador in 1992 and spread rapidly throughout most of the Americas causing losses of over $2 billion to aquaculture (Brock et al. 1995). TSV outbreaks devastated farmed shrimp production in Texas and South Carolina in 1995 and 1996, respectively. Pacific white shrimp *P. vannamei* are especially susceptible to TSV. Laboratory studies suggest that Atlantic white shrimp *P. setiferus* infected with TSV also may suffer high mortalities (Overstreet et al. 1997).

White Spot Virus (WSV) was first reported from northeast Asia in 1992 and spread throughout the region during the 1990s, causing devastating declines in farmed shrimp production (Flegel 1996). WSV was identified in captive shrimp in South Carolina in 1997, although archived DNA samples suggest a WSV-like virus may have existed in the southeastern US as early as 1988. Evidence suggests WSV infections in South Carolina originated from the wild. At present, there are not enough data to determine if the WSV infections identified in captive white shrimp resulted from a recent introduction from Asia or from indigenous carriers. WSV is unique among shrimp viruses in that it infects a variety of crustaceans; WSV-like genetic material has been found in samples from white shrimp, grass shrimp, fiddler crabs, blue crabs, and stone crabs in South Carolina. These crustaceans may be carriers of WSV that could re-infect wild as well as farmed shrimp.

Yellow Head Virus (YHV) was recently recognized, and described for the first time in Thailand in 1992, where total crop losses were reported in some affected ponds within 3 to 5 days (Flegel et al. 1995). This disease syndrome may have plagued intensive production of black tiger shrimp *P. monodon* in many parts of Asia for nearly a decade (Lightner 1996). In Asia, YHV generally co-occurs with WSV. Juvenile shrimp, including indigenous US species, are particularly susceptible to YHV infections. YHV was reported with WSV in Texas in 1995, and there is some evidence suggesting that YHV was present with WSV in South Carolina, although this has not been confirmed.

Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV) is widely distributed in aquaculture facilities in Asia and in the Americas, and is particularly lethal to some strains of Pacific blue shrimp *P. stylirostris*. IHHNV was first described from aquaculture facilities in Hawaii in the early 1980s (Lightner 1996). Shrimp that survive IHHNV infections can transfer the disease to their offspring as well as to other shrimp. Pacific white shrimp infected with IHHNV often vary greatly in size and develop deformities.

Risk Management Efforts in South Carolina

The Department recognized the threat of shrimp viruses to the state's aquaculture industry and wild shrimp populations as early as 1988. In 1990, working with the South Carolina Sea Grant Consortium, an international conference was convened to discuss the issues associated with introductions and transfers of marine species. The conference was followed by a workshop to identify and evaluate the risks associated with the culture of nonindigenous shrimp in South Carolina. In addition to potential release and escape of nonindigenous shrimp, workshop participants identified

Shrimp Virus *continued on next page*

***Shrimp Virus** continued from previous page*

the introduction of nonindigenous pathogens as a potential risk.

Following the 1990 workshop, the Department under authority of the state's Marine Fisheries Laws require shrimp growers to obtain permits to culture nonindigenous shrimp. Initial permits were designed to manage risk by minimizing potential escapes by a series of specific requirements to screen discharge waters.

In 1994 Taura Syndrome was first found to be caused by a pathogenic virus. In 1995 the disease spread to Texas wiping out most of the farmed shrimp crop. In response to the risk posed by this newly recognized pathogenic virus, the Department modified the nonindigenous shrimp importation permit conditions. Protocols were imposed to assure the quality of imported seed which had to be obtained from hatcheries with a history of producing disease-free post-larvae. Only stocks from hatcheries with ongoing efforts that met US Marine Shrimp Farming inspection and disease protocols were allowed into the state (Lotz et al. 1995). Despite tightened policy and controls, a batch of post-larvae infected with TSV was imported. TSV quickly spread throughout the state causing an estimated 60% production loss in the 1996 farmed shrimp crop.

The 1996 permit failed to prevent the importation of shrimp viruses because disease diagnostic methods were not capable of reliably identifying diseases before importation, and because it was impossible for the Department to regulate out-of-state hatcheries. Two important lessons were learned from the 1996 TSV outbreak: an in-state quarantine of imported post-larvae was the most efficient and effective manner for farmers to identify diseased shrimp before they were stocked into ponds and infected the entire facility; and plans for viral-agent containment or eradication during and following acute outbreaks need to be quickly developed and validated.

The Department further modified shrimp grower permits in 1997 using the lessons learned from the 1996 TSV outbreak. In addition to effluent screening and stock source evaluations, the 1997 permit required:

- a 25-day quarantine for post-larval shrimp imported from hatcheries for which the disease history was questionable;
- a plan of action for controlling the spread of disease when outbreaks occur, and;
- self-monitoring for viruses to provide early detection, allowing time to mitigate damage.

The Department also recommended that pond sediments be dried and treated with lime to oxidize organic material that could contain virus particles before seed shrimp were stocked in them. As a result of these controls, the South Carolina shrimp farming industry produced a healthy shrimp crop in 1997. TSV infected seed stocks were identified and destroyed in quarantine. Although a TSV-WSV outbreak occurred on one farm causing high mortalities, the 1997 controls allowed early detection and prevented the infection from spreading to nearby facilities.

Over the last several years, the Department has concluded that an in-state hatchery operated by the shrimp farming industry would help provide a pathogen-free seed supply. The Department is currently working with industry and the South Carolina State Legislature to develop plans for an in-state hatchery. When this hatchery is operational, it will eliminate the need for a seed shrimp quarantine period, thereby increasing production and profitability.

As mentioned earlier, two other potentially important sources of shrimp viruses are carrier organisms in ship ballast water and frozen seafood product. Invasions of a wide range of aquatic nuisance species, including several crustaceans, are linked to ballast water discharge (Carlton 1992; Cohen and Carlton 1998). In many countries, farmed shrimp are harvested during the acute phase of virus outbreaks to salvage part of the crop and minimize losses. Infected shrimp are frozen and sold in the US for consumption or for use as fishing bait. Viable virus particles have been found in frozen shrimp in the US (Nunan et al. submitted). If introduced into local waters as bait or as waste, these tissues could represent a vector for infection of indigenous crustaceans. In response to the potential threats of shrimp viruses to natural shrimp populations, the US Joint Subcommittee on Aquaculture convened a multi-agency working group to define the scope of the shrimp virus issue and to develop recommendations for resolving it. This working group developed a report summarizing the current state-of-knowledge about the threat of shrimp viruses and recommended that a formal risk assessment be conducted (USJSA 1997).

Minimizing the effects of shrimp farming on natural resources is a complex problem that will continue to require the Department to maintain a balance between natural resource protection and the need to develop an ecologically sound in-state aquaculture industry. Unfortunately scientific information to support regulatory policy and permit processes is incomplete. Supplies of post-larvae that can be stocked directly into ponds do not always exist. Diagnostic methods for detecting shrimp pathogens are not standardized and do not have the sensitivity or specificity needed for regulatory and enforcement actions. Moreover, existing diagnostic tools are particularly ineffective at detecting diseases in young post-larval shrimp, which is the life stage of greatest concern. Disinfection protocols are costly and impractical to implement at the scale of most farm operations, plus new viruses continue to emerge.

Development of a sustainable shrimp aquaculture industry in South Carolina, as well as elsewhere, will require a commitment from the private sector, the scientific community, and government to work together to develop environmentally acceptable and effective production controls, in addition to a dependable supply of healthy seed stocks.

Craig Browdy is a researcher at the Waddell Mariculture Center, and A.F. Holland is the Director of the Marine Resources Research Institute, South Carolina Department of Natural Resources, POB 809, Bluffton, SC 29910.

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Overview of the International Ruffe Symposium

by Jeff Gunderson

While zebra mussels are affecting both industry and the environment, they are not causing the economic consequences first predicted. Likewise the Eurasian ruffe *Gymnocephalus cernuus*, a small perch-like fish, will also certainly have negative effects on ecosystems it invades, but reports presented at the International Ruffe Symposium held in Ann Arbor, Michigan, offer hope that it may not be as destructive or as costly to the Great Lakes as first feared. The symposium, held in March 1997 and sponsored by the Minnesota and Michigan Sea Grant College programs, brought together 100 managers, administrators, and scientists from around the world to present results of their ruffe research.

Ruffe in Lake Superior

Ruffe (pronounced rough) are small, aggressive fish native to Eurasia. In their native waters, ruffe have little commercial value or use as a source of human food. They were first discovered in the St. Louis River, the main tributary to western Lake Superior, in 1986; they were probably introduced via the freshwater ballast of ocean-going vessels in the early 1980s. Literature at that time suggested that ruffe mature and reproduce quickly, adapt to a wide variety of environments, and compete with native fishes for food. As a result, ruffe were considered a serious threat to the delicate predator-prey balance vital to sustaining healthy commercial and sport fisheries across North America.

True to those early predictions, within five years ruffe became one of the most abundant fish in the St. Louis River. They quickly spread eastward along the south shore of Lake Superior (nearly 200 miles). Ruffe were also found in Thunder Bay, Lake Superior (Ontario), and Thunder Bay, Lake Huron (Michigan), most likely carried in ballast water of ships from the Port of Duluth/Superior. Populations in both Thunder Bays are small but reproducing.

Are Yellow Perch at Risk?

To the surprise of many of the symposium's participants, most of the research showed little, if any, negative effect on yellow perch populations. Even in the St. Louis River, where ruffe are dominant and yellow perch have declined, there is a lack of evidence that the decline is a result of ruffe, according to Chuck Bronte (US Geological Survey, Ashland, WI). He and his co-authors compared population fluctuations of yellow perch and other native fish species in the St. Louis River to fluctuations of fish populations in a Lake Superior bay with very few ruffe. They found that yellow perch and other fish population fluctuations were as likely the result of natural changes as of the presence of ruffe.

Colin Adams (University Field Station, Glasgow, Scotland) and Ian Winfield (NERC Institute of Freshwater Ecology, Cumbria, England), studying lakes in the United Kingdom where ruffe have invaded within the last 15 years, also concluded there is no evidence that ruffe have affected the European perch (a species very similar to our yellow perch). Russian scientist Victor Mikheev (A.N. Severtsov Institute of Ecology and Evolution, Moscow), through his review of the Russian literature, concluded that European perch do not seem to be affected by ruffe where they naturally coexist.

Ray Newman (University of Minnesota, St. Paul) reported on the food preferences of ruffe and other species in two Lake Superior tributaries. Newman's research showed that ruffe and yellow perch generally prefer and consume different food items, although there was some diet overlap.

This is good news because even small reductions in important Great lakes species would have large economic effects. Peter Leigh (National Oceanic and Atmospheric Administration, Silver Spring, MD) examined the benefits and costs associated with a proposed Great Lakes ruffe control program. Leigh found that a decision not to institute an 11 year, $12 million ruffe control program could result in substantial net economic losses. Under the "minimum effect" scenario (a projected decrease of 10% in yellow perch populations, and a 1% decrease in both walleye and lake whitefish), annual reductions in commercial and US sport fishery benefits reach nearly $24 million. Annual "moderate" and "maximum" reductions reach nearly $120 million and $215 million respectively.

There was also information presented that was not good news for yellow perch and the ecosystem. Carl Richards (Natural Resources Research Institute, University of Minnesota, Duluth) presented preliminary results from experiments conducted in a backwater lake adjacent to the St. Louis River. These experiments showed that compared to yellow perch, ruffe cause significant reductions in several groups of **benthic** food items which are important to native fishes. These experiments showed that ruffe have negative effects on the growth of yellow perch when they occur together, presumably because ruffe reduce the availability of food. Ruffe were also found to affect several measurements associated with nutrient and energy cycling within aquatic ecosystems. It is unclear at this point how these types of changes will affect native fish populations.

Whether or not ruffe disrupt the ecosystem in obvious ways, they will certainly be a nuisance to anglers and commercial fishermen. Complaints of interference with fishing are common where ruffe are abundant.

Lake Superior Ruffe from Danube River, Not Baltic Sea

Another startling revelation was that genetic differences between ruffe from the Danube River in Slovakia and ruffe from the Baltic Region of Europe may be large enough to suggest they are separate species. Carol Stepien (Case Western Reserve University, Cleveland, OH) made this discovery while looking for the source of the Lake Superior introduction. Currently, ruffe from both the Danube and Baltic regions are identified as *Gymnocephalus cernuus*, but according to Stepien's findings, they are as genetically distinct from each other as other closely-related species *(G. cernuus, G. baloni, G. schraetser)* are from each other. Further work will be required to determine if the two variations of *G. cernuus* are truly separate species.

Previously, scientists speculated Lake Superior ruffe may have arrived in the ballast of ships coming from the Baltic Sea region, specifically St. Petersburg, Russia. Stepien, however, determined that Lake Superior ruffe likely hitched a ride in ships' ballast coming from the Black Sea, into which the Danube River flows. Ruffe collected from the Danube River in Slovakia are identical to ruffe from the St. Louis River, and ruffe from the recent infestation in Lake Huron near Alpena, MI, are identical to the ruffe in the St. Louis River.

Some Ruffe Eat Fish Eggs, Some Don't

Ruffe in Europe are known to eat the eggs of several species of fish that are similar to Great Lakes whitefish and lake herring, which are important commercial species. Some researchers found eggs to be very important to ruffe's diet, others did not. Although many fish eat the eggs of other fish without affecting them, there is concern regarding predation on the autumn/winter incubating eggs of whitefish and herring because ruffe can attain high densities and feed more actively in cold water than other fish.

Ruffe are Ideal Invaders

The ruffe's traits make it an ideal invading species; they are adaptable to a variety of habitats, they mature quickly, and they spawn over an extended period. Ruffe feed primarily at night and prefer murky water, which may help them evade predators. They also have an extremely well-developed lateral line system (a kind of long-range sensory system) that allows them to detect and capture prey in complete darkness. John Jansen (Loyola University, Chicago, IL) reported that ruffe use a thrust-and-glide approach to feeding, which helps reduce noise created by their swimming, allowing them to detect prey with their lateral line better than perch can.

Ruffe are Difficult to Stop

It is unlikely that the spread of ruffe can be stopped, although chemicals may be useful in certain circumstances. Michael Boogaard (US Geological Survey, LaCrosse, WI) reported that the **lampricide** TFM could be used to kill ruffe, although there might be some mortality among nontarget fishes. Thomas Busiahn (Chair of the Ruffe Control Committee, US Fish & Wildlife Service, Ashland, WI) pointed out some problems encountered when the use of toxicants was considered. Busiahn said that a plan to slow the spread of ruffe along the south shore of Lake Superior by using TFM was not implemented because of opposition from a variety of groups. Because of public resistance to chemical use, he said any proposal to use chemicals will require careful evaluation (see "The Battle to Control Ruffe" in *ANS Digest,* Vol. 1, No.2).

Chemicals are not the only way to stop ruffe. A voluntary ballast water exchange program, bait harvest restrictions, other regulations, and education programs have been implemented. To date no ruffe have been found in inland waters, which suggests these efforts may be working.

Other methods of ruffe control have been tried. Victor Mikheev (Severtsov Institute, Moscow) reported that intensive fishing with a variety of trawls, seines, and traps was used in an attempt to reduce ruffe numbers in some Russian lakes. The intense fishing proved unsuccessful, because ruffe numbers actually increased due to compensatory growth and reproduction. Mikheev reported some success with reducing ruffe numbers in a small lake by increasing the number of predators, like pike perch and northern pike. However, Kathy Mayo (US Geological Survey, Ashland, WI) reported that a predator enhancement program attempted in the St. Louis River was not effective because the predators selected native prey and avoided ruffe, and because the predators never became as abundant in the river as had been hoped.

Peter Sorensen (University of Minnesota, St. Paul) described alarm pheromones—odors released by injured fish that cause others of the same species to flee or hide. Sorensen reported that when an extract of ruffe skin was introduced into tanks of ruffe, they avoided the areas with the odor. Although there is some concern that ruffe might acclimate to the odor, this alarm pheromone could be useful as a repellent.

Ruffe are Here to Stay

Even though the symposium ended on a note of guarded optimism, it remains important to take steps to ensure that ruffe aren't carried inland. Boater and angler education is extremely important in this respect. Ruffe are prospering in North America, and they will continue to spread. Unlike the effects of oil spills and chemical pollution, which can sometimes be reversed, ruffe will change our North American fish communities forever. The door must be closed to new introductions, because once they get here, they will be here to stay.

Abstracts from the International Symposium on Biology and Management of Ruffe can be ordered for $5 by calling Minnesota Sea Grant at (218) 726-6191.

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***Shrimp** continued from page 33*

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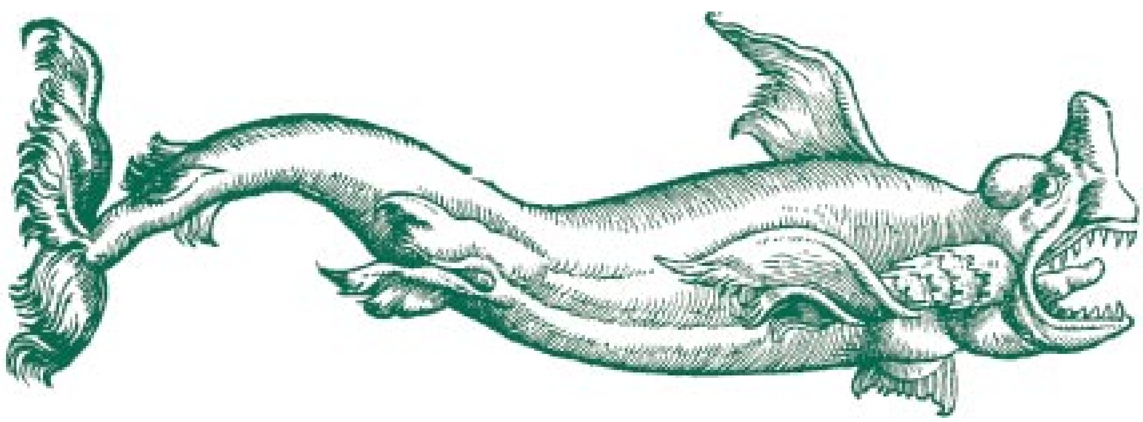

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